SEAWATER DIELECTRIC CONSTANT AT L-BAND: HOW CONSISTENT ARE NEW PARAMETRISATIONS INFERRED FROM SMOS AND LABORATORY MEASUREMENTS?

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ABSTRACT

The accuracy of the Sea Surface Salinity (SSS) retrieved from L-Band radiometer measurements is strongly dependent on the accuracy of the modelling of the dielectric constant (ε). Two new ε parametrizations have recently been developed based on one hand on the Soil Moisture and Ocean Salinity (SMOS) satellite multi-angular brightness temperature measurements and on the other hand on new laboratory measurements. These two approaches are fully independent. These new ε parametrizations are compared with each other and with the ε models previously in use in the SMOS, Soil Moisture Active Passive (SMAP) and Aquarius SSS retrievals. The two new ε parametrizations are found to be in closer agreement than with earlier parametrizations for most common ocean conditions.

We will further study to which extent the recent SMOS CCI+SSS v3 reprocessing confirms the above results and could help resolve remaining inconsistencies.

Index Terms— SMOS, salinity, microwave, ocean remote sensing

1. INTRODUCTION

The key information for retrieving the Sea Surface Salinity (SSS) from L-Band radiometric measurements is the relationship that links the dielectric constant of sea water (ε) with SSS and Sea Surface Temperature (SST). This is particularly challenging as the sensitivity of L-Band brightness temperature, Tb, to SSS is low, -0.8K pss^{-1} at 30°C to -0.4K pss^{-1} at 5°C in V-polarization, 40° incidence angle, for open ocean SSS conditions. Last year, two independent studies have proposed new ε parametrizations. The first ε(SSS,SST) parametrization [1] has been derived based on pseudo dielectric constant values retrieved from the Soil Moisture and Ocean Salinity (SMOS) multi-angular measurements following [2] approach. The other ε(SSS,SST) parametrization [3] has been derived from novel and very precise ε laboratory measurements. Our study aims at comparing brightness temperatures, Tb, simulated with these two new parametrizations and with ε relationships currently in use in SMOS, Aquarius and Soil Moisture Active Passive (SMAP) processing: the [4] (named KS hereafter) model used in the SMOS processing and the [5, 6] (named MW hereafter) model used in the Aquarius and SMAP processing. In the following, we recall the main characteristics of various ε models, we describe their comparison, we discuss the results and the perspectives of that study.

2. DIELECTRIC CONSTANT MODELS

Both [1] (named BV hereafter) and [3] (named GW hereafter) consider the physical approach of [7] (named ST hereafter) which rationalize the SSS and SST dependencies of the various parameters involved in the Debye ε model. According to ST, ε can be written as:

$$\varepsilon(T,S) = \epsilon_1(T) + \frac{\epsilon_s(T).(1-\alpha\cdot S) - \epsilon_1(T)}{1 + j\omega\tau(T)} - \frac{j\sigma(T,S)}{\omega\varepsilon_0}$$

where j is the imaginary unit, T indicates temperature dependency, ε_1 is the dielectric constant at very high frequency, ε_s is the static (zero frequency) dielectric constant of fresh (S=0) water, τ is the relaxation time of fresh water in seconds, ω is the angular frequency of oscillation of the electric field, σ is the conductivity of sea water. In that equation, all the salinity (S) dependencies are contained in σ and in the term $(1 - \alpha.S)$, contrary to earlier parametrizations which involved S dependencies in τ, ε_1, ε_s. ST adjusted an α value, independent of T and S, that provides Tb(SSS,SST), very similar to the one derived with MW model (see Figures 1 and 9 in [1]). However, the ST and MW ε(SSS,SST) did not fully agree with SMOS retrieved pseudo-dielectric constant. [1] revised the ST parametrization by adding a T dependency to α, as it was first envisaged by ST. BV uses fresh water parameters as in MW. On another hand, GW derived new parametrizations for both fresh and salty water parameters based on new ε measurements, particularly detailed in the low SST range, and considers both S and T dependencies in α.

3. RESULTS

The difference between Tb derived with various ε models and Tb derived from the GW model (TbGW) are on Figure 1 for vertical polarization at 40° incidence angle. This incidence angle is the closest sampled by the three missions, SMOS, SMAP and Aquarius. Results at nadir (not shown) and 40° incidence angle are very close. Figure 1, left, displays the difference for most commonly observed open ocean SSS, between 30 and 38 pss. The SST dependency differs the most with KS at low SST and the less with BV

above 15°C, apart from a ~0.1K systematic difference that could be corrected by vicarious calibration of Tb (the so-called Ocean Target Transformation, OTT, for SMOS and Ocean Target Calibration, OTC, for Aquarius). At a given SST, the SSS dependency of the differences is always within 0.05K and the SSS difference is very similar with BV and MW models (increased ΔTb when increasing SSS). The same is observed if we replace MW freshwater parameters by GW freshwater parameters in BV. Over the ranges of SST and SSS plotted on Figure 1, the lowest standard deviation of the difference, stdd, are observed with BV, followed by MW (Table 1). When looking at SSS fresher than 30pss (Figure 1, right and Table 1), the spread of the differences for a given SSS, i.e. the SST dependency of the differences remain about the same as for higher SSS. On another hand, for a given SST, the SSS dependency of the differences with respect to TbGW increases in a similar way with BV and MW, slightly less with KS. In that range of SSS, BV is closer to MW than to GW (Table 1), while the SSS dependency at given SST obtained with GW is closer to the one of KS (Figure 1, right). As expected from Figure 1, the stdd with respect to GW increases when extending the range of SSS towards lower values.

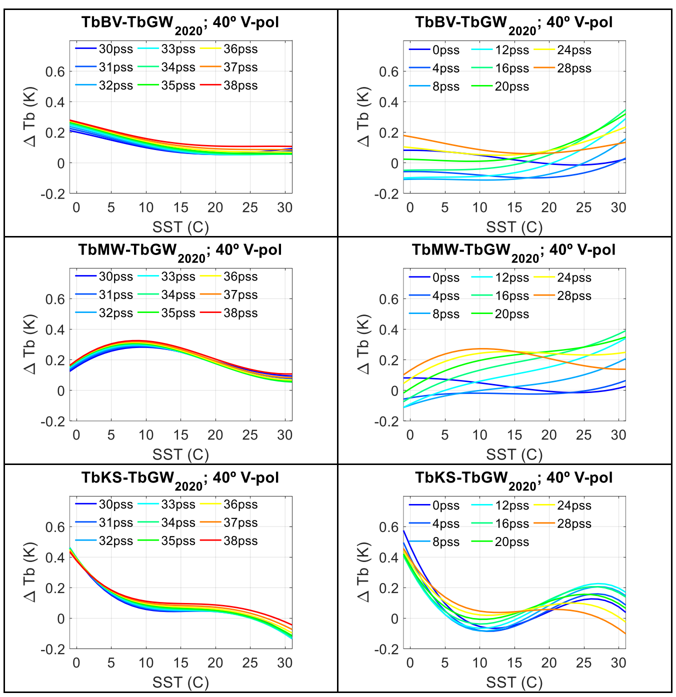

Figure 1: Differences in Tb, V-polarization, 40° incidence angle. First row) TbBV minus TbGW; second row) TbMW minus TbGW; last row)TbKS minus TbGW. Left column) for most SSS encountered in open ocean (30 to 38pss); right column) for fresh SSS (less than 30pss).

Table 1: std difference between various Tb binned in 1° SST step from -1 to 31°C and 1pss step

SSS range (pss)	[30 38]	[0 30[
Std(TbBV-TbGW) (K)	0.063	0.102
Std(TbBV-TbMW) (K)	0.076	0.066
Std(TbMW-TbGW) (K)	0.079	0.120
Std(TbKS-TbGW) (K)	0.121	0.121

We further look at the same Tb differences but in the plane of ocean observed SSS and SST pairs (Figure 2, Table 2). Actually, some pairs plotted on Figure 1 are not observed in the real ocean (e.g. large SSS in cold waters) and differences there could have minor influence on ocean retrieved SSS. We again observe a better agreement between GW and BV, then with MW.

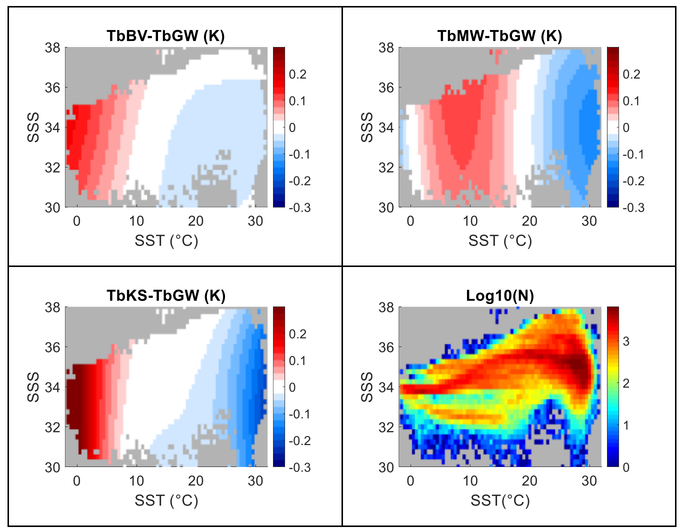

Figure 2: Differences in Tb (V-pol, 40°incidence angle) and number of points (bottom right), in the SSS, SST plane for SSS and SST pairs most often observed in the open ocean (70°N-70°S). The mean over all (SSS,SST) pairs (see Table 2) has been subtracted.

Table 2: Mean and std difference of Tb for all (SSS, SST) pairs shown on Figure 2 (Note that these statistics are not weighted by the number of points in each (SSS, SST) box)

	Mean (K)	Std (K)
TbBV-TbGW	0.1009	0.0592
TbBV-TbMW	-0.0802	0.0737
TbMW-TbGW	0.1928	0.0842
TbKS-TbGW	0.0753	0.1092

4. DISCUSSION AND PERSPECTIVES

The Tb agreement between the new BV ε parametrization derived from SMOS retrieved pseudo dielectric constant and the new GW ε parametrization derived from laboratory measurements is striking over open ocean SSS and SST conditions, TbGW and TbBV being closer than with TbMW and TbKS. The absolute difference (~0.1K) between GW and BV modelled Tb might be an artefact of SMOS OTT correction that is model dependent. At low SST, a ~0.1K relative difference remains between TbBV and TbGW which origins is unclear. When dealing with SSS lower than 28pss, the use of a Debye model ensures a consistency between the various models within about 0.2K, BV being closer to MW. However, no SMOS observations have been used to adjust BV parametrization in this SSS, SST range so these results have to be taken with great caution.
These results will be deepened at the time of the IGARSS conference taking advantage of new SMOS retrieved pseudo dielectric constant generated by the ongoing European Space Agency (ESA) Climate Change Initiative (CCI) version 3 reprocessing (see X. Perrot abstract #3248). This reprocessing reduces errors in SMOS retrieved parameters, by performing a more precise OTT correction (use of realistic SSS variability instead of a climatology for the OTT computation), by using the European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 hourly parameters as priors instead of the ECMWF 3-hours forecasts and by collocating the SMOS retrieved parameters with the Integrated Multi-satellitE Retrievals for GPM (IMERG) rain rates, allowing an efficient filtering of SMOS rainy measurements. It furthermore uses the BV dielectric constant model for retrieving SSS. Hence the analysis of the SMOS-CCI v3 retrieved SSS and retrieved pseudo-dielectric constants should allow to refine uncertainties in BV relationship.

5. REFERENCES

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